Indirect Impact of Atmospheric Aerosols on an Ensemble of Deep Convective Clouds

Research Highlight

This paper extends the previous cloud-resolving modeling study concerning the impact of cloud microphysics on convective-radiative quasi-equilibrium (CRQE) over a surface with fixed characteristics and prescribed solar input, both mimicking the mean conditions on Earth. The current study applies sophisticated double-moment warm-rain and ice microphysics schemes that allow for a significantly more realistic representation of the impact of aerosols on precipitation processes and on the coupling between clouds and radiative transfer. Two contrasting cloud condensation nuclei (CCN) characteristics are assumed, representing pristine and polluted conditions, as well as contrasting representations of the effects of entrainment and mixing on the mean cloud droplet size. In addition, four sets of sensitivity simulations are also performed with changes that provide a reference for the main simulation set.

As in the previous study, the CRQE mimics the estimates of globally and annually averaged water and energy fluxes across the Earth's atmosphere. There are some differences from the previous study, however, consistent with the slightly lower water vapor content in the troposphere and significantly reduced lower-tropospheric cloud fraction in current simulations. There is also a significant reduction of the difference between pristine and polluted cases, from about 20 W/m2 to about 4 W/m2 at the surface and from about 20 W/m2 to about 9 W/m2 at the top of the atmosphere (TOA). The difference between homogeneous and extremely inhomogeneous mixing scenarios, about 20 W/m2 in the previous study, is reduced to a mere 2/1 W/m2 at the surface/TOA. An unexpected difference between previous and current simulations is the lower Bowen ratio of the surface heat flux, the partitioning of the total flux into sensible and latent components. It is shown that most of the change comes from the difference in the representation of rain evaporation in the sub-cloud layer in the single- and double-moment microphysics schemes. The difference affects the mean air temperature and humidity near the surface, and thus the Bowen ratio.

The differences between various simulations are discussed, contrasting the process-level approach to the impact of cloud microphysics on the quasi-equilibrium state with a more appropriate system-dynamics approach. The key distinction is that the latter includes interactions among all processes in the modeled system.

Reference(s)

Grabowski WW and H Morrison. 2011. "Indirect impact of atmospheric aerosols in idealized simulations of convective-radiative quasi-equilibrium. Part II: Double-moment microphysics." Journal of Climate, 24, 1897-1912.

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Cloud-Aerosol-Precipitation Interactions